Hydrol. Earth Syst. Sci. Discuss., 12, C1115–C1142, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C1115/2015/

Hydrology and Earth System Sciences Discussions
Open Access

Interactive comment on "Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream" *by* M. Majerova et al.

M. Majerova et al.

milada.majerova@gmail.com

Received and published: 18 April 2015

Thank you for your feedback. We copied your comments and provided our responses below.

Reviewer 1

The manuscript draft "Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream" describes a rare opportunity to investigate the basic reach scale effects of beaver colonization over a gradient of dam influence. The others opportunistically leverage a fantastic dataset collected by Schmadel et al 2010 before the stream reach was colonized, by collecting data for several more years as beavers built at least 10 dams over a 750 m distance. Overall the topic is interesting, and the text quite well-written. The type of data collected are fairly basic, but as the authors note there is little "quantitative" study of beaver dam impacts to date. Beaver impoundment will have varied pros and cons in regard to stream restoration efforts that will be highly influenced by the morphological attributes of the degraded system and restoration goals (both physical and biological). There is an amazing opportunity to improve degraded streams, particularly incised channels in the USA western states, by simply allowing beaver to return (not trapping them), and perhaps actively helping them get a foothold. With the USA state of Utah actively including beaver management in their statewide stream management strategy, studies such as this are strongly needed.

1. Although I generally agree with the overall approach taken here, some things should be better quantified and clarified for this data to be more thoroughly interpreted in the context of seasonal variability. It seems 2010, the "beaver impact" end-member presented here, was perhaps unusually dry (Figure 2), and may have led to complicating human hydrological effects such as enhanced irrigation near the study reach. We have also added explanation in the discussion – page 854, L5.

2010 was indeed drier year due to less snowfall. The snow water equivalent at its peak was about 500 mm in 2008 and 2009, and 300 mm in 2010. However, precipitation accumulation in 2010 increased in late spring/ summer, and the cumulative amounts were comparable with that of 2008 at the end of the water year (October). While the discharge in 2010 could have been influenced by irrigation practices in the nearby field, irrigation usually occurs only from mid-May to mid- or late-July at the latest and therefore only had a potential impact during this time. However, water rights require irrigation in this area to stop when the flow in Blacksmith Fork reaches a minimum instream flow. Because of low flows in 2010, irrigation stopped earlier than usual (likely early July, personal communication, Kelly Pitcher, Hardware Ranch operations). It is also important to note that the trend of gaining conditions persist past the irrigation season (with more beaver dams being built) (Figure 3). This suggests that reach gains in 2010 were due primarily to groundwater influences rather than irrigation influences.

HESSD
12, C1115–C1142, 2015

Interactive Comment

In our opinion, the human impact is likely not a driving factor of the hydrologic and temperature changes we observed.

"While the discharge in 2010 could have been influenced by irrigation practices in the nearby field, irrigation usually occurs only from mid-May to mid- or late-July at the latest and therefore only had a potential impact during this time. However, due to drier conditions in 2010 and water right requirements, irrigation stopped earlier than usual (likely early July). The dominant hydrologic processes influencing the study reach clearly changed over the period of three years and the trend of gaining conditions persisted past the irrigation season (Fig. 3). This suggests that reach gains in 2010 were due primarily to groundwater influences rather than irrigation influences."

2. Further, no attempt is seemingly made to normalize stream temperature results to atmospheric temperature patterns of a given year, making conclusions based on inter-annual comparison less certain.

Additional subplots of air temperature and solar radiation have been added to Figure 4 for 2008, 2009, and 2010 to show the relative differences of weather between years. The one-way ANOVA comparison of air temperature showed no statistically significant differences between individual years ($p > 0.05$) which suggests that air temperature is not a driving factor of stream temperature observed over the years. In addition, ΔT normalized by air temperature showed a gradual increase from 2008 to 2010, similar to Figure 4, suggesting changes within the reach. When one-way ANOVA was applied to normalized daily ΔT values for the common days when both water and air temperature are available each year, we again found a significant difference from year to year ($p < 0.01$) suggesting that the between year variability in air temperature is not creating the differences observed within each year. Further, we applied a one-way ANOVA to ΔT normalized by flow at the upstream boundary to investigate the impacts of flow variability between years. We still found a significant difference ($p < 0.01$) between 2008 and 2010 suggesting that flow conditions are not the only factor influencing ΔT values.

HESSD
12, C1115–C1142, 2015

We chose to leave Figure 4 as a relative net change in temperature (normalized to the upstream control temperature) to illustrate changes within the study reach as this will make it easier to compare with other studies. We did, however, add the following text to page 851, L1 to clarify that the between year water temperature differences were not due to differences in air temperatures. Also similar text has been added to Methods section – page 849, L 19.

"To determine if weather conditions were influencing the water temperature differences between years, we first compared air temperature conditions through a one-way ANOVA and found no statistical differences between individual years ($p > 0.05$). We further compared daily ΔT values normalized by air temperature for the common days when both water and air temperature were available. We found a significant difference in the average $\Delta T/Tair$ values ($p < 0.01$) between years. This suggests that the between year variability in air temperature is not controlling the observed ΔT patterns."

3. Finally, no straight forward process-based explanation of why increased water levels and retention along this reach caused a system-wide transition from "losing" to "gaining" is presented.

We have added the statement below regarding the losing-gaining transition in the manuscript – we added this near page 854, L29 (in HESSD). Note that we have updated a number of figures within the MS to address the reviewers' comments. The old figure number and "New" figure number will be provided within the responses below.

"The significant increases in the groundwater table (Figure 8, which is now the New Figure 7) were likely due to increased water surface elevations in the beaver ponds for consecutive years. The localized increases in groundwater elevations are further elevated each spring due to high flows, inundation of the flood plain, and general high surface water elevations throughout the reach. As the flow and surface water elevations drop throughout each summer, there are positive groundwater gradients towards the stream throughout this season and, therefore, the reach gains water. These opposing results from dilution gaging and groundwater levels highlight the importance of temporal scales and repeated measurements considered in this present work. They also indicate that without this consideration, the differences between measurement techniques can lead to contradicting conclusions as discussed within Schmadel et al. (2014)."

Major comments: 4. I assume local air and groundwater temperatures were monitored over the course of this experiment? The results presented here should be put in their context. Reduced peak flows are expected after beaver dams, but what was the avg snowpack each year? Precip? There is clearly much less water flowing through the reach in 2010 overall compared to previous years if one integrates under the Q curves (Figure 2); this "environmental" effect will likely impact peak flows, losing/gaining hydraulics, water temp, residence times. Also, this "dryer" year may have resulted in enhanced local field irrigation which is independent of beaver dam impacts. The authors refer to this loosely on pg 850 and elsewhere- and 80% increase in reach Q over two years is likely not driven primarily by a few ponded areas, unless a reasonable process-based explanation can be presented. As the paper stands it is difficult for the reader to parse direct effects of beaver colonization from inter-annual environmental variability and associated human impact (irrigation); this renders the results much less "quantitative" than the authors imply (eg pg 853, L20).

Yes, air temperature was measured in the reach and has been incorporated into Figure 4. The groundwater temperature was not measured over time. The cumulative precipitation for each year is now shown in SI Figure 5 to provide a context for the differences in discharge between years. While there is a lot less water flowing through the reach in 2010, we are focusing on illustrating the change in discharge over the study reach (shown as differences between downstream (outflow, PT1252) and upstream (inflow, PT515) discharge (Figure 3)). We present the data in terms of differences and percent differences (i.e., normalized by upstream values) rather than absolute values to illustrate the potential groundwater influences during the three year study period (Figure 3,

HESSD

12, C1115–C1142, 2015

Interactive Comment

5, 6, 9, 10, 11, SI1) and seasonal variability (Figure 2 and 4).

The concerns regarding the explanation of the gaining/losing patterns are provided above in our response to comment 3.

5. The "window of detection" concept well detailed by Payn et al 2009 should be reviewed and commented on in the context of your results. Beaver dams seem to force surface and subsurface flowpaths outside of the main channel which cause strong variability when making closely spaced in-stream evaluations, but may integrate at larger scales (windows) to result in muted changes.

Good point. We have added the following language to page 854, L22 in the HESSD.

"The window of detection varies as a function of stream characteristics, including storage zone dimensions and exchange rates, and stream velocity and discharge (Harvey et al., 2000).In turn, it dictates which subsurface exchange flow paths are captured within tracer break through curves (e.g., Ward et al., 2013). Because the changes to the study reach between years influenced the window of detection and the reported mass recoveries, our conclusions are based on the net changes to flow (%ΔQ) that are insensitive to a changing window of detection."

6. The local discharge patterns described at the top of pg 850 could be influenced by a series of "return flows" from upper impounded areas.

Reach scale flow conditions reflect year to year variability as well as beaver dam building activities (Figure 3). All of the side channels were initiated and returned to the main channel within the study reach. The variable local discharge patterns did influence the sub-reach scale results when comparing flow conditions for all three years and this was acknowledged within the text (see HESSD page 854, L17).

7. Similarly, it is noted on pg 854 that the up-gradient "control" reach lost more water each year of the study, while the impounded reach gained more water. Could something about the higher water table, increased capture area be forcing greater return

HESSD
12, C1115–C1142, 2015

flow from upstream? Is there any way to parse stream water from new GW inputs chemically based on already collected data?

This is a good question. Based on head gradients and prior work in the upper control reach, we believe that much of the gaining and losing in the upper reach is more perpendicular to the channel than parallel or down-watershed. There may, however, be longer flow paths from the control reach to the beaver impacted reach that are being rerouted to the surface due to changing groundwater elevations in the study reach. Unfortunately, we do not have any data to support or refute these ideas.

8. Tracer mass-recovery methods should be better defined, and a mass recovery of -103.7% does not make sense conceptually.

We have expanded the tracer recovery methods (HESSD, page 846, L12). There was a mistake in the original manuscript (HESSD p. 852, L11) stating the mass recovery %. The percentages reported are not mass losses, but % gross water losses. This has been corrected within the manuscript and some additional comments (see below) regarding error estimates have been included. Please see HESSD page 852, L11.

"To estimate tracer mass losses and gross stream losses, mass recoveries were quantified using (Payn et al., 2009):

(equation cannot be displayed)

"For 2008, the error in flow estimates for the individual sub-reaches was about 8% for both Q and %ΔQ. For 2010, the errors ranged from 6% to 28% for Q and 8% to 29% for %ΔQ. Most of the error was due to incomplete tracer mixing and larger errors in 2010 were attributed to higher variability in flow and flow paths. The mass recoveries showed that the percent of mass loss changed significantly from 2008 to 2010. In 2008, the mean percent mass losses for individual sub-reaches were sequentially -2.8, -12.9, -18.1, -18.8, and -4.7%. In 2010, the mean percent mass losses were -69.0, -0.2, -8.3, -62.0, -7.6% for the same sub-reaches." – page 852, L11

HESSD

12, C1115–C1142, 2015

9. There is discussion regarding the increase in residence times on Pg 852, but this does not include the residence times of unrecovered mass/water, so these increases in recovered mass residence time likely underestimate true increases in system residence time.

True. We have added a statement to Sub-reach Scale Responses acknowledging this. Please see HESSD page 852, L22.

"The residence time of unrecovered mass was not included in mean residence time estimates."

10. Although alluded to in the discussion, the concept of patchiness could be more strongly presented/commented on here (see http://rsfs.royalsocietypublishing.org/content/2/2/150). Beaver dams likely increase system productivity by creating varied habitats in close physical contact with one another as the author's mention. This increase in "productivity" may be difficult to quantify with simple point temperature and water flux/head measurements, but they can perhaps be commented on.

We agree that it is difficult to capture spatial heterogeneity (patchiness) with point temperature measurements. This is emphasized within page 856, L14-L26, page 857, L6-L12 in the discussion and further illustrated within Figure SI4D. SI4D highlights the importance of the spatial scale when one is studying the impacts of beaver on stream systems. However, we have expanded this section to provide further emphasis on this topic (page 856, L24).

"Spatial heterogeneity (patchiness) and spatial patterns in heterogeneity change with spatial scale (Cooper et al., 1997). Since most of the ecological interactions in heterogeneous streams happen in conditions that are different from mean conditions, they cannot be captured with point measurements, or with models that focus on understanding average conditions (Brentall et al., 2003, Grünbaum, 2012). This highlights the need to concentrate on variables and processes that capture spatial patchiness at different spatial scales in stream ecosystems."

11. It is not clear why a 2006 image is used in Figure 1 to show a post-dam world, and the beaver ponding is digitized (?) from some other unknown image. Either both images should be directly presented or the 2010 image should be used for this figure. The text/symbol size in this figure needs to be increased.

We have updated Figure 1 by combining the previous Figure 1 with Figure 7. The text size in Figure 1 has been increased. Also, Figure SI4 was changed to include aerial imagery from multiple years.

12. Consider shifting Figure 10 to supplemental, and including the current Supplemental IR figure as new Figure 10.

Based on the response to comment 11 above, we believe that Figure 10 should remain in the text. While we understand the value of thermal image in understanding the spatial variability on temperatures, we decided to only include it in the SI because it is from a different time period. We felt it was important to have a consistent representation of study time period (2008-2010) and changes that occurred within that period. This led us to only using the thermal image to illustrate differences in temperature between sections with and without beaver dams.

13. Figure 4: Can you plot all of these panels together? They are difficult to compare as-is.

These data could be plotted together, but the overlap of the time series will make much of it indistinguishable. We have added solar radiation and air temperature for each year to this plot to help with the between year comparison.

Minor comments: (next time please use a continuous line numbering system)

The line numbering was formatted by journal.

14. pg 840 l2- delete "increasing"

HESSD

12, C1115–C1142, 2015

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Deleted.

15. l15-mean temperature in the outgoing thalweg? Try to be more specific with these important conclusions. state some conclusions here on local GW heads.

Yes, the temperature increase at the reach scale in the outgoing thalweg. We have added the following sentence about groundwater in the abstract – HESSD p. 840, L14.

"In addition, we observed an increase in groundwater elevation in the sub-reaches."

16. 841- perhaps mention that beaver dams break up the average stream slope into a series of punctuated head drops. Overall this intro is in great shape.

Thank you. We have added the following statement in our Introduction – p. 841, L4.

"Within the stream channel, beaver dams break up the average hydraulic gradient into series of disrupted head drops and flat ponded sections. This change in average hydraulic gradient increases the potential for hyporheic exchange (Lautz and Siegel, 2006)."

17. 843 L19- how old are the relic surfaces?

We do not know exactly and have decided to remove this text.

18. 844 L1- The underlying goals of the restoration project should be clearly stated L4-"roughly around 2005?" surely somebody knows the correct timing

This effort was not clearly documented and the availability of information is limited. Based on prior conversations with people within the Division of Natural Resources, the primary goal was to move the stream away from the buildings and horse pastures.

19. L12- Beaver dam height measured how? (eg top to base below water?)

Beaver dam heights were measured at the downstream face as a difference between channel bottom right below the dam and top of the dam at the crest.

20. L19-extrapolaton seems a bit weird here- 13.3 dams/km based on 10 dams over

HESSD

12, C1115–C1142, 2015

750 m- as you arbitrarily defined the reach length, and if the upper control section was included this number would fall

The upper section is only a “control” reach for the discharge comparison. There is no beaver activity (at least in period of 2008 to 2010 presented here) in this section. Our intention was only to provide an estimate of dam density within the study reach which resulted in 10/0.75km = 13.3 dams/km.

21. 845 L15- where were these pressure transducers installed relative to channel morphology? In a side pool?

The upstream pressure transducer (PT515, inflow) was installed close to river bank (RR) in a section between two bends with an average bed slope of 0.017. Based on 2009 data, the average depth recorded at the inflow (PT515) was 0.13 m and minimum and maximum values were 0.08 m and 0.57 m, respectively. The downstream pressure transducer (PT1252, outflow) was installed near a foot bridge about 1.5 m from river left with an average bed slope of 0.0239. Based on 2009 data, the average water depth recorded at the outflow (PT1252) was 0.16 m and minimum and maximum values were 0.08 m and 0.32 m, respectively. The pressure transducer at the upstream end of the control reach (PT0) was installed about 1.0 m from river right with an average bed slope of 0.018. Based on 2009 data, the average depth recorded was 0.21 m and minimum and maximum values were 0.09 m and 0.37 m, respectively.

22. L18- what is this full range of flow conditions?

We have added the following information about specific flows measured (min and max). – page 845, L19.

“The lowest flow measured was 157.4 L s-1 at PT1252 and the highest flow measured was 1509.6 L s-1 also at PT1252.”

23. L20- FloMate 2000?

Yes, 2000. Changed within the text.

24. L28- are these return flows surface or subsurface? this seems like a “result”

These were surface return flows – small side channels created either by beaver or due to overland flows from the beaver ponds. We have clarified this in the text. (HESSD page 845, L28).

25. 846 L3 include range of injected masses. Na+ also effects conductivity.

We have included ranges of NaCl in the manuscript (HESSD page 846, L5). Also please see text added below.

“Tracer injection masses ranged from 600 to 3300 g as NaCl and were varied to achieve large enough responses in electrical conductivity above background for dilution gauging and mass recovery purposes.”

26. L11ish- introduce the mass recovery, concurrent gains/losses methods here presented by Payn et al 2009, mass recovery is later determined but it is not stated how this was done

We have included the following information (with equation) about mass recovery in our Data Collection section of the Methods – HESSD page 846, L13.

“To estimate tracer mass losses and gross stream losses, mass recoveries were quantified using (Payn et al., 2009):

(equation cannot be displayed)

27. L23- where were these temp measurements made? 0.6 m depth? attached to stake in water column?

We have added this specification in the manuscript (HESSD page 846, L26). Also, please see below.

“The temperature sensors were attached to metal stakes, placed in the middle of the channel, approximately halfway through the water column. Individual sensors were

HESSD

12, C1115–C1142, 2015

wrapped in aluminum foil to reduce solar radiation influence in slower moving waters."

28. 847 L10- ice buildup influenced by dams? This can effect winter SW/GW exchange

We agree that the ice buildup in the beaver ponds can influence surface/ground water exchange. But the major reason for excluding data from the winter months was ice buildup around pressure transducers themselves which could influence the data accuracy. We have added the following clarification in the manuscript (HESSD page 847, L10).

"Data from the winter months were excluded from the analysis because they were influenced by ice buildup around the pressure transducers."

29. L17- how is error on parameters a and b determined? Some main details should be stated here so the paper can stand alone without Schmadel et al 2010.

We have added the following statement about a and b parameters in the manuscript (HESSD page 847, L15).

"The regression parameter, a and b, were estimated through nonlinear regression and were the minimum sum of squares occurred. Uncertainty in these parameters was assessed from values within the 95% joint confidence region (Schmadel et al., 2010)."

30. L20** are these changes normalized to local air temps somehow??

Please see response to comment 2 above.

31. 849 L5- Make sure to state temp data were collected above the impounded water upstream of dams, not just right above a dam and right below which would make less sense

Good point. We have corrected this in the Data Collection and Data Analysis sections (page 846, L24; page 849, L6) and added more detailed description of sensor placements.

HESSD

12, C1115–C1142, 2015

“The temperature sensors were initially placed in the flowing water to ensure well mixed flow. The sensors downstream from the beaver dams were placed outside of the scour pool. The temperature sensors were attached to metal stakes, placed in the middle of the channel, about halfway through the water column. Individual sensors were wrapped in aluminum foil to reduce solar radiation influence in slower moving waters.”

32. L25- how did snowpack/melt differ between years?

We have added Figure 5 to the SI to show the differences in snow water equivalent and precipitation accumulation for all three years. Please see our response to comment 1 above.

33. 850 L4- include error estimates on these values, the coauthors previous work clearly indicates this should be done

We have included error estimates on flow Q and dQ in the manuscript, as well as added error envelopes in Figure 2 and Figure 3.

34. 851 L12-14 move to Discussion section

Great point. We have moved this statement to discussion (page 855, L24).

35. L18 “in the end” too casual

We have deleted it.

36. L20 what about the lateral transect info form Subreach 5?

We have added the following statements in the results and discussion sections (page 852, L3; page 858, L3).

“The head gradients from the cross-section of wells in sub-reach 5 show an increase in groundwater elevation over time and depict a positive gradient on one side of the channel and negative gradient on the other.”

“The positive head gradients on river left (facing downstream) shown in Figure SI 2

HESSD
12, C1115–C1142, 2015

illustrates why sub-reach 5 is gaining water as shown in Figure 7. It is important, however, to also note that this sub-reach is also losing water on river right. However, sub-reach 6 is gaining water due to the main and side channels meeting again (Fig.1, Fig. 8)."

37. 852 L2 note these patterns show a potential for water flux, not flux itself- you may be comparing pressure from two different flow paths

We agree that there is a potential for different flow paths in our study reach. However, our intent is to use head gradients to illustrate relative changes over time in relation to surface water elevations. To make this clear, we edited a statement in methods (page 848, L19) and added a sentence to the discussion (page 854, L29).

"To further understand hydrologic impacts of beaver dam construction and to illustrate the channel and groundwater elevation gradient changes over time, these data were grouped by each sub-reach were evaluated for 2008, 2009, and 2011."

"Although, there is a potential for different flow paths in our study reach and head gradients do not necessarily translate into fluxes, we use the groundwater elevations to illustrate the relative changes in relation to channel surface water elevations over time."

Please note figure captions uploaded with this reply do not cover the entire caption from the original manuscript. There is only limited space for captions in the uploading window. For better reference, please find full captions here:

Figure 1. Aerial image from 2006 (pre-beaver period) and beaver dams constructed between 2009 and 2010. The main beaver dams are numbered from 1 to 10 from upstream to downstream and the time of dam construction is noted in the table. The study reach was further divided into 6 sub-reaches. The spatial scales investigated are illustrated below the map. The most downstream beaver dam and beaver pond are located in the old channel but overlap in the Beaver Dam Scale schematic in this figure. Channel in 2006 is illustrated by black outlines while flowing and ponded water area in

HESSD
12, C1115–C1142, 2015

2010 are represented by different shades of blue.

Figure 2. Daily average discharge estimated from continuous pressure transducer records spanning 2008-2010 (A-C). The black dashed line represents upstream, inflow conditions at PT515 and the red solid line represents downstream, outflow conditions at PT1252. The individual 95% confidence intervals around discharge estimates are represented by grey shading.

Figure 3. A) Change in discharge over the study reach calculated from daily average flows where ΔQ is the discharge at outflow (PT1252) minus the upstream discharge at inflow (PT515). Positive values represent increases in discharge and negative values represent decreases in discharge. B) %ΔQ is the percent change relative to the discharge at inflow (PT515). The 95% confidence interval in three different shades of grey correspond with each individual year. Arrows represent time of individual beaver dam construction. Blue and red arrows correspond with year 2009 and 2010, respectively, while the arrow size is proportional to size of the dam.

Figure 4. Average daily temperature (absolute) representing reach scale responses at inflow (PT515, black dashed line) and outflow (PT1252, red solid line) during 2008 (A), 2009 (B), and 2010 (C). Average daily air temperature (D) and average daily solar radiation (E) show similar weather patterns for all three years.

Figure 5. A) Reach scale change in temperature (ΔT) calculated from temperatures at outflow (PT1252) minus the temperature at inflow (PT515). B) %ΔT is the percent change relative to the temperature at inflow location (PT515). Positive values represent warming throughout the reach and negative values represent cooling relative to the upstream inflow temperature at PT515. Arrows represent time of individual beaver dam construction. Blue and red arrows correspond with year 2009 and 2010, respectively, while arrow size is proportional to size of the dam.

Figure 6. Change in discharge (ΔQ) and temperature (ΔT) over the study reach from 2008 to 2010. Five day period in July was used as an example of shorter temporal

scale. The %ΔQ and %ΔT are relative to the discharge and temperature at the upstream inflow location (PT515). The %ΔQ were averaged over a one hour interval, while %ΔT represents 5-minute temperature values.

Figure 7. Groundwater elevation throughout the study reach grouped by individual sub-reaches and water surface elevation in the channel for each sub-reach. The groundwater elevations were measured four times in 2008, five times in 2009, and four times in 2011. The water surface elevation in the channel represents the average yearly value for each sub-reach. There is a gradual increase in groundwater elevation and channel water surface elevation in all sub-reaches over the years.

Figure 8. Sub-reach stream discharge (Q) estimates for 2008 and 2010 representing longitudinal flow variability before and after beaver colonization. %ΔQ is calculated from flow at the end of the sub-reach minus the flow at the beginning of the sub-reach relative to the upstream value.

Figure 9. Spatial variability in stream temperature throughout individual beaver dams (BD). Temperature differences (ΔT) values were calculated based on 10-minute temperature records from locations downstream and upstream of the beaver dam and pond. These data illustrate that there is a time lack between air temperature and stream temperature and also that there can be measurable differences in temperatures at the beaver dam spatial scale that vary diurnally. It further shows the variability in temperature differences between the dams.

Figure 10. A) Daily ranges (daily maximum minus daily minimum values) of temperature differences downstream and upstream (ΔT) of each beaver dam (BD) based on 10-minute temperature records. Beaver dam 7 and 8 were considered to be one complex. The air temperature (blue line) and stream temperature at the inflow (PT515, black dashed line) illustrate diurnal pattern while the time offset between the two can be observed. B) 24-hour moving average of ΔT.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C1115/2015/hessd-12-C1115-2015-supplement.zip

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 839, 2015.

HESSD

12, C1115–C1142, 2015

Interactive Comment

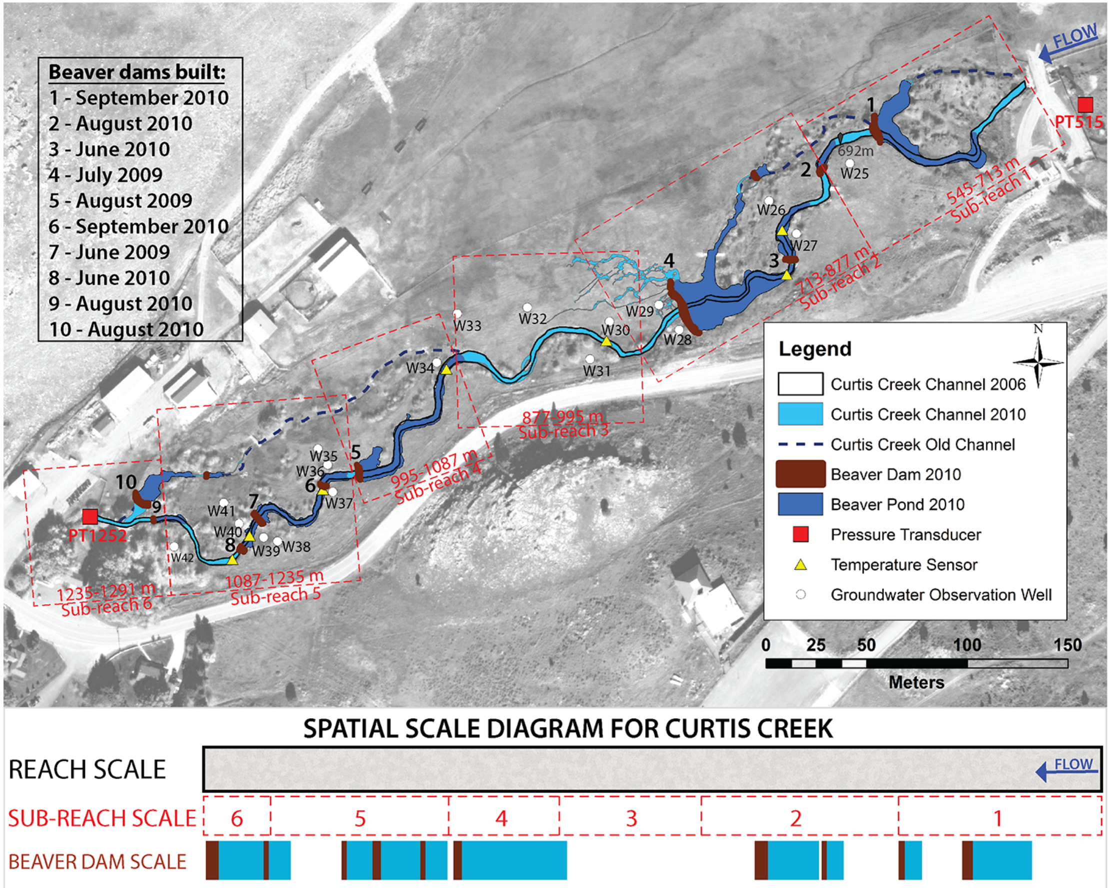

Fig. 1. Aerial image from 2006 (pre-beaver period) and beaver dams constructed between 2009 and 2010.

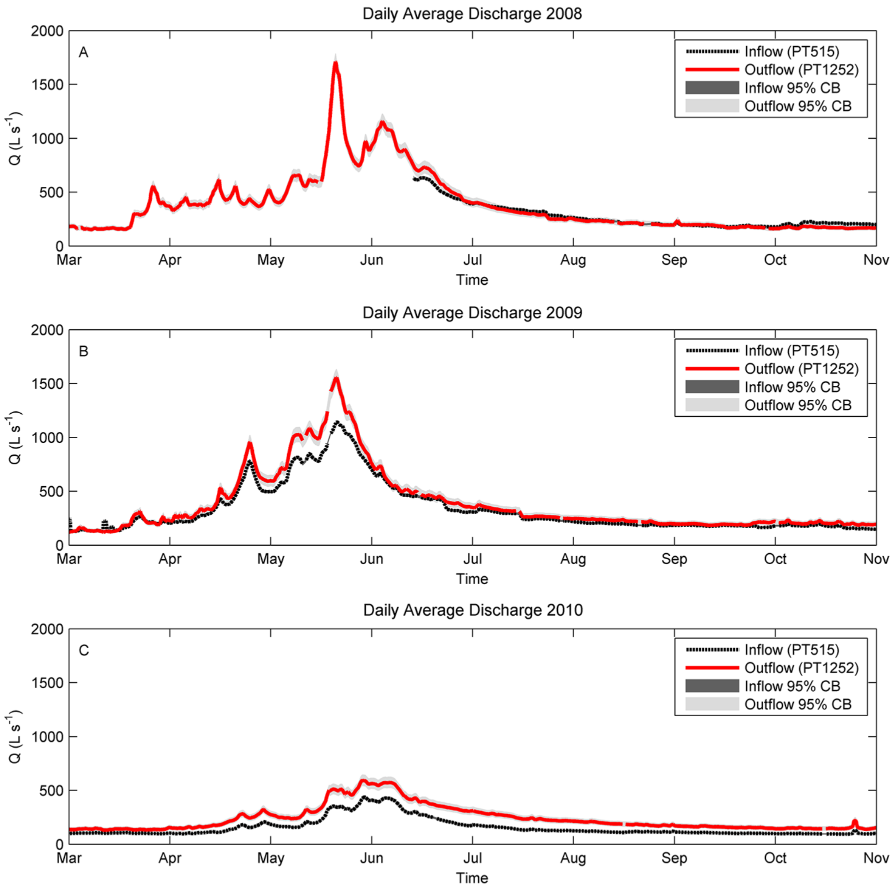

Fig. 2. . Daily average discharge estimated from continuous pressure transducer records spanning 2008-2010 (A-C).

HESSD
12, C1115–C1142, 2015

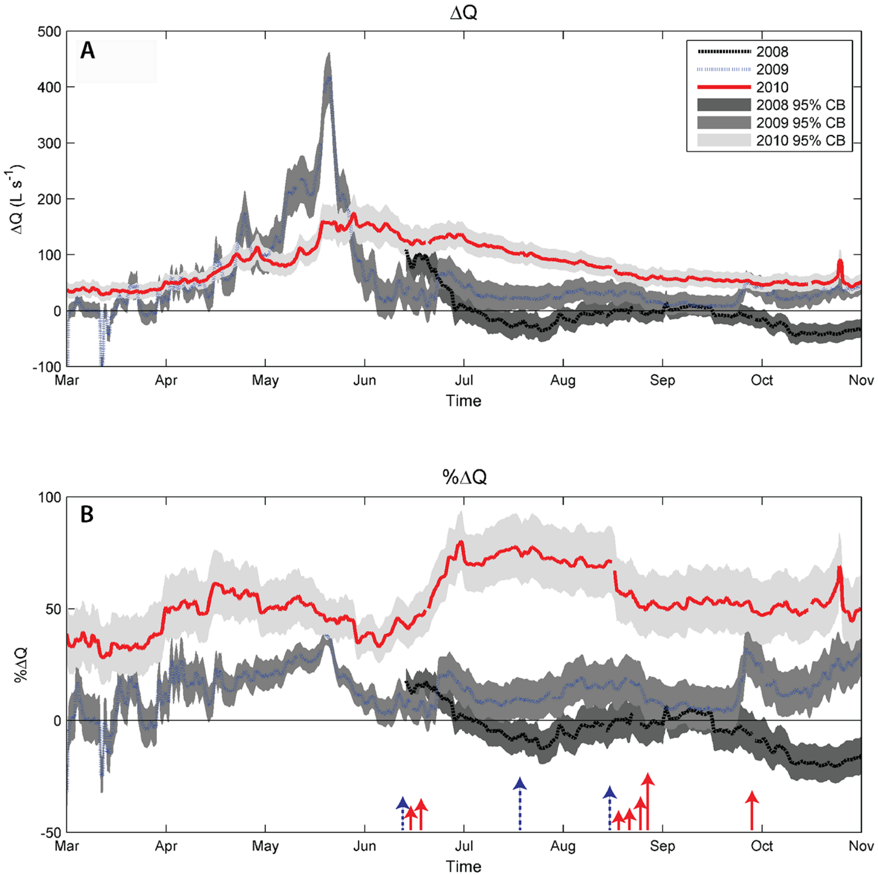

Fig. 3. A) Change in discharge over the study reach calculated from daily average flows where ΔQ is the discharge at outflow (PT1252) minus the upstream discharge at inflow (PT515).

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

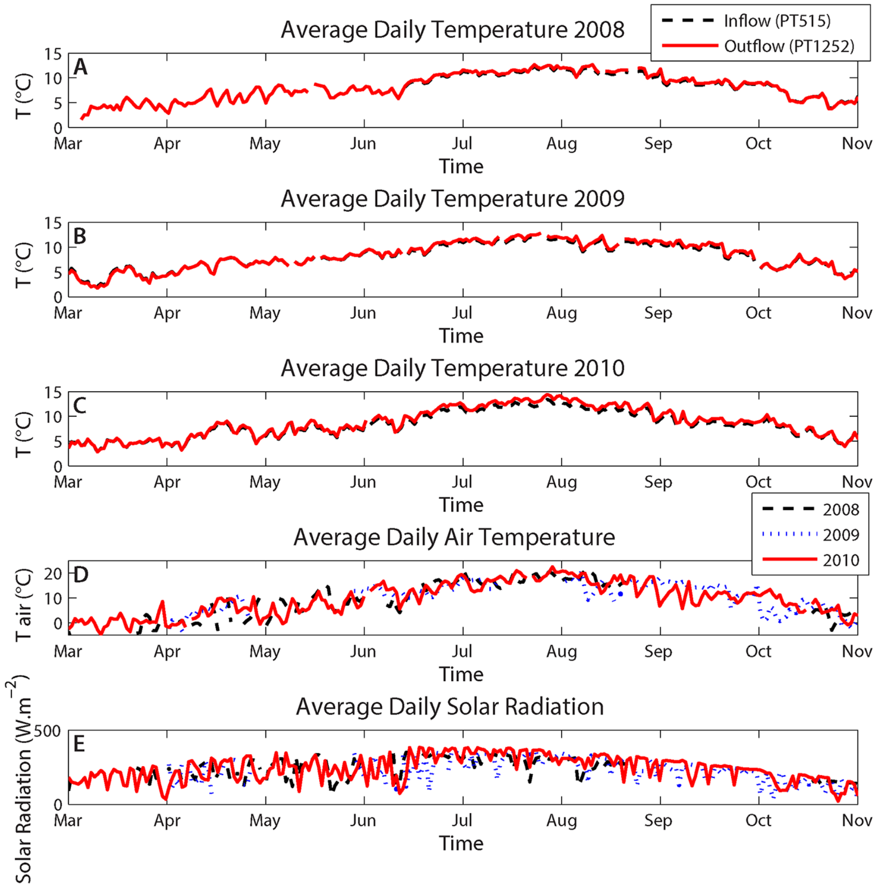

Fig. 4. Average daily temperature (absolute) representing reach scale responses at inflow (PT515, black dashed line) and outflow (PT1252, red solid line) during 2008 (A), 2009 (B), and 2010 (C).

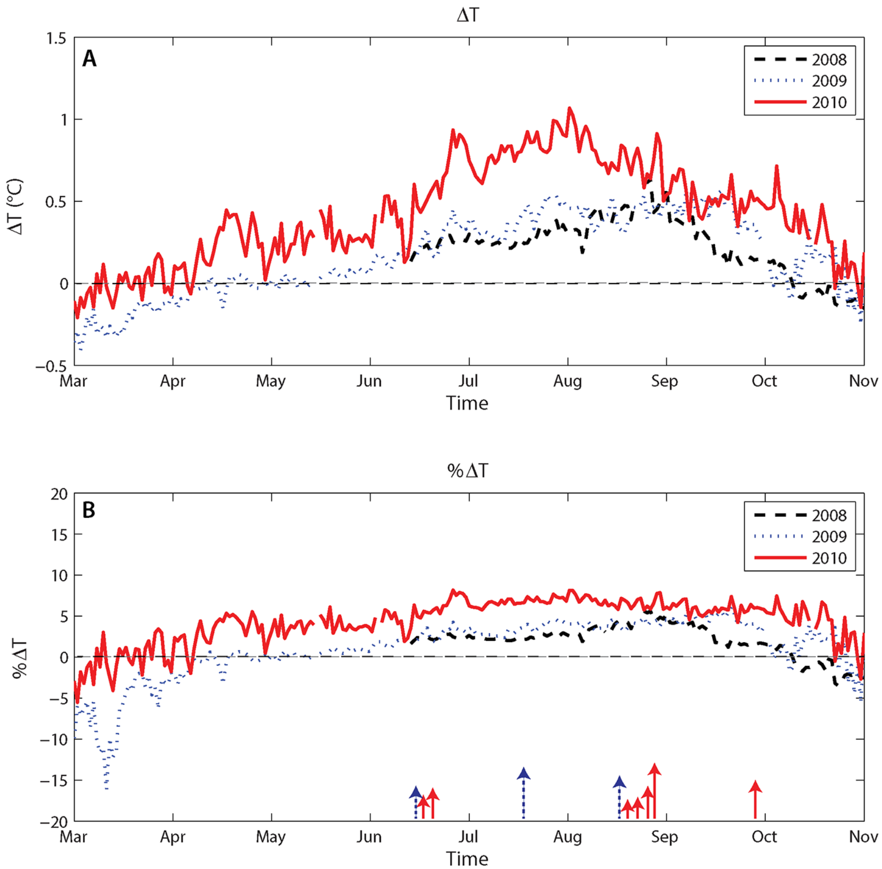

Fig. 5. A) Reach scale change in temperature (ΔT) calculated from temperatures at outflow (PT1252) minus the temperature at inflow (PT515).

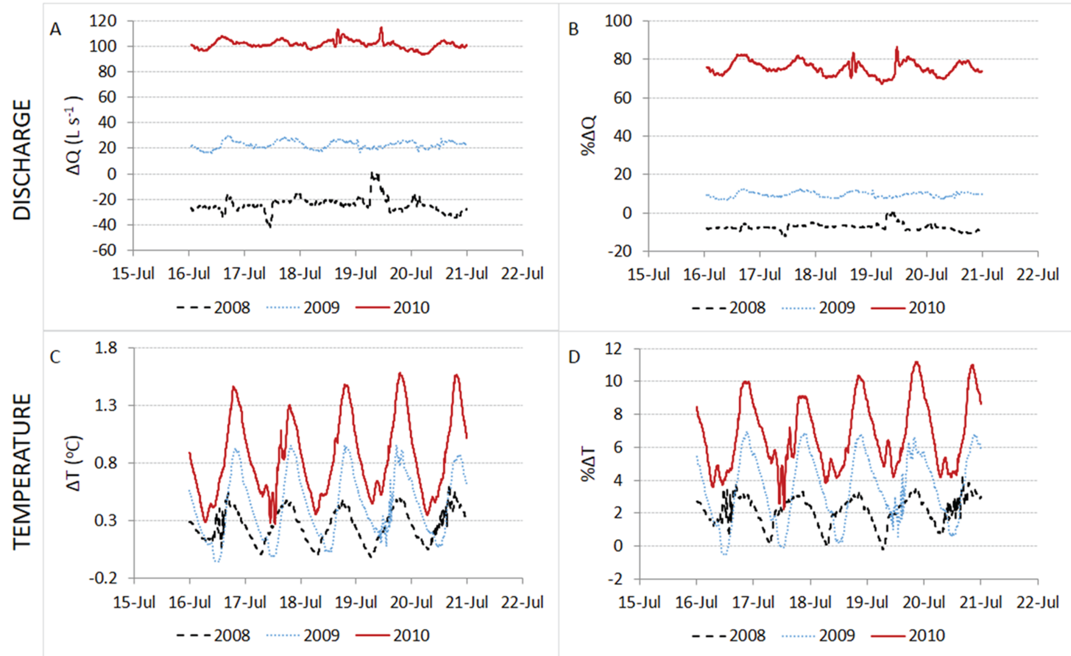

Fig. 6. Change in discharge (ΔQ) and temperature (ΔT) over the study reach from 2008 to 2010.

HESSD
12, C1115–C1142, 2015

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

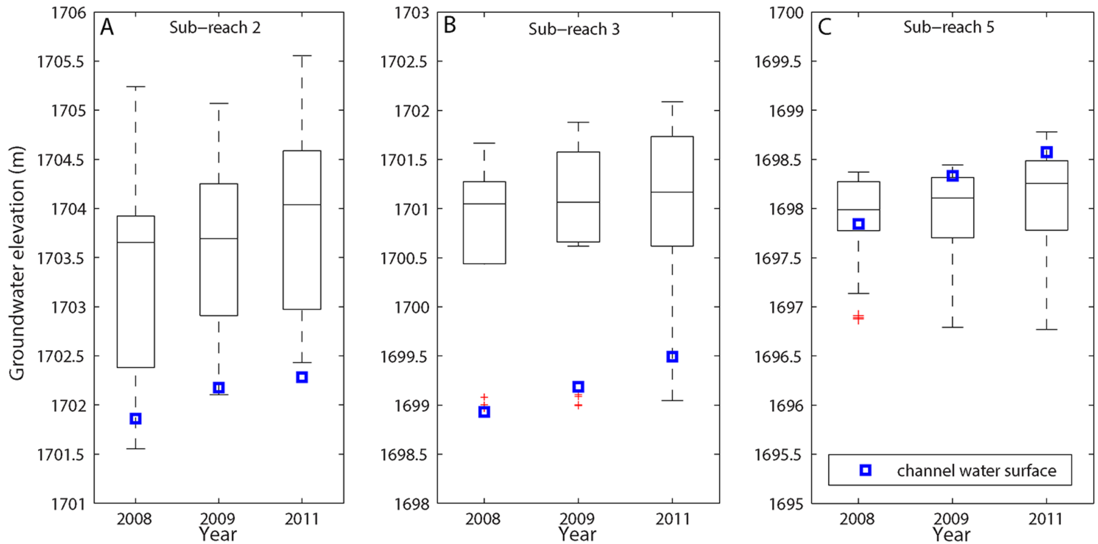

Fig. 7. Groundwater elevation throughout the study reach grouped by individual sub-reaches and water surface elevation in the channel for each sub-reach.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

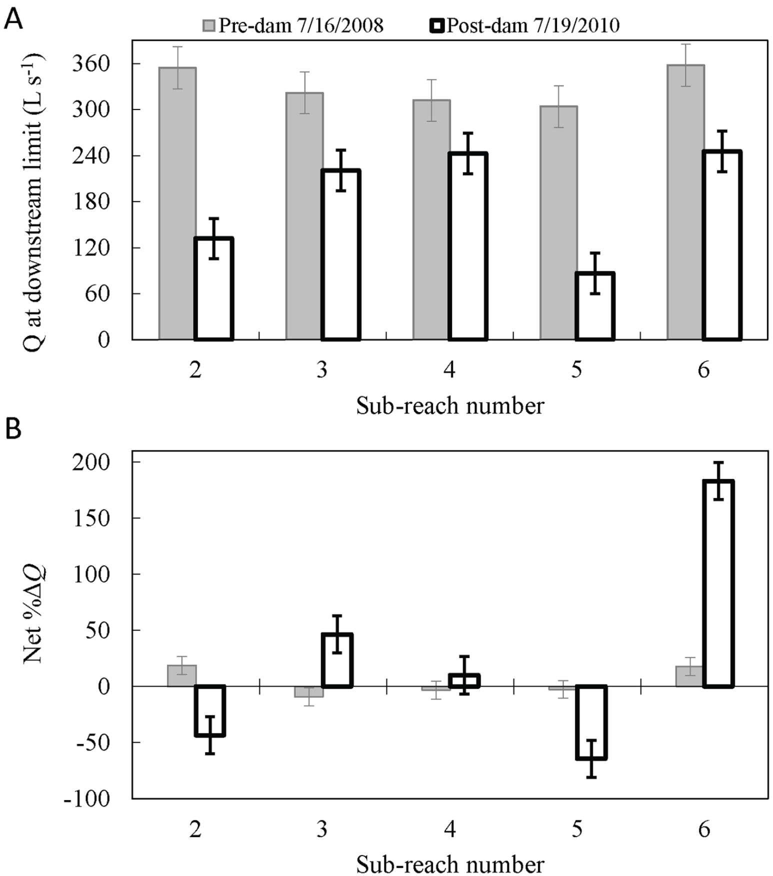

Fig. 8. Sub-reach stream discharge (Q) estimates for 2008 and 2010 representing longitudinal flow variability before and after beaver colonization.

HESSD
12, C1115–C1142, 2015

Interactive Comment

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

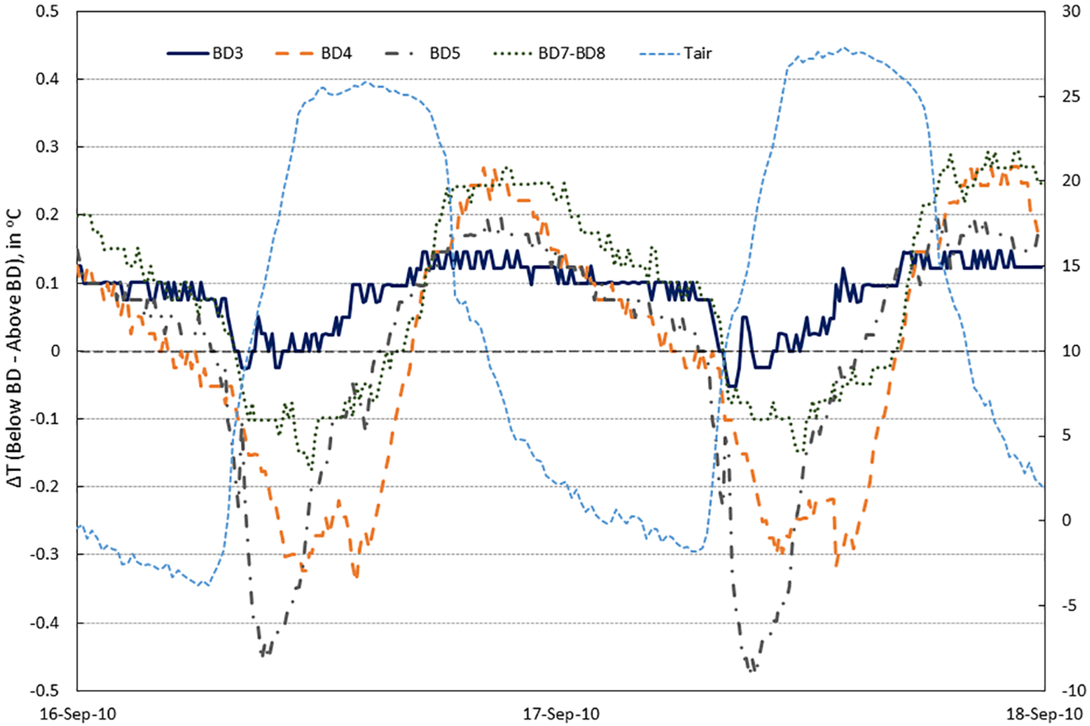

Fig. 9. Spatial variability in stream temperature throughout individual beaver dams (BD).

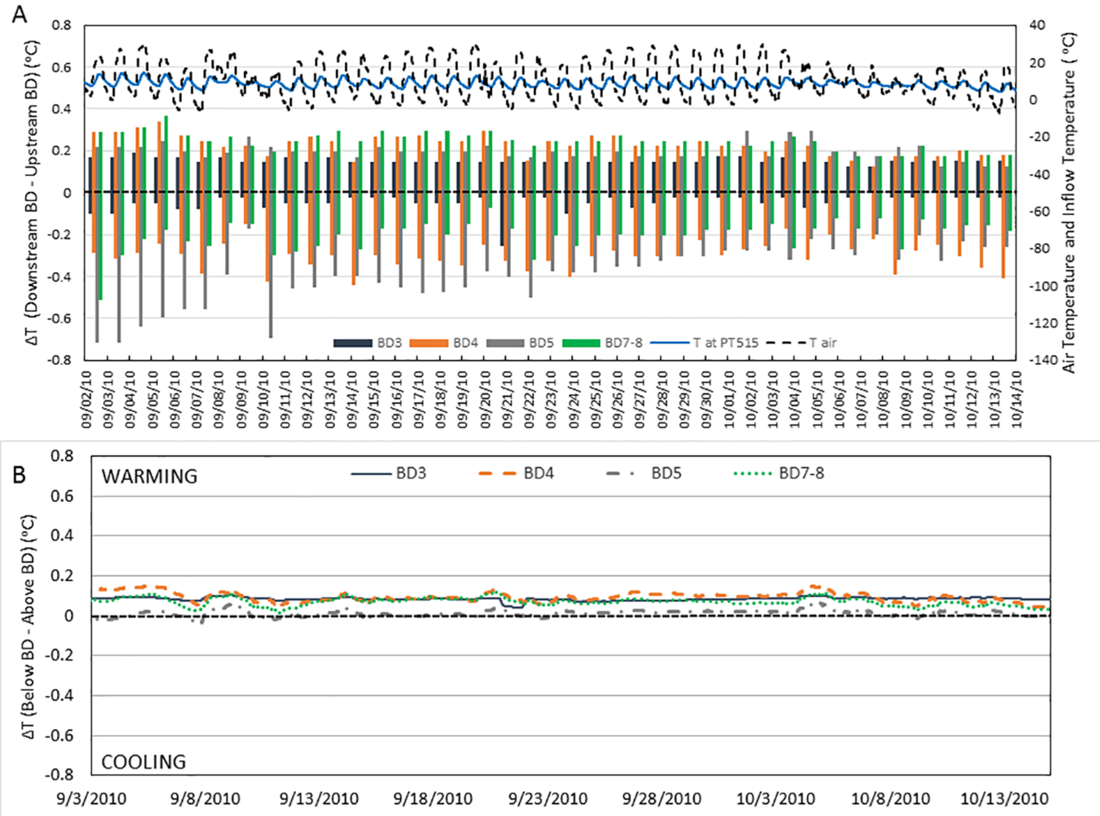

Fig. 10. A) Daily ranges (daily maximum minus daily minimum values) of temperature differences downstream and upstream (ΔT) of each beaver dam (BD) based on 10-minute temperature records.